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SHUTTLE GET-AWAY SPECIAL EXPERIMENTS

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This presentation describes two shuttle Get-Away-Special (GAS) experiments built by McDonnell Douglas to investigate low-g propellant acquisition and gaging. The first experiment, which was built under internal research and development funding, was flown on shuttle mission 41-G in October 1984. The second experiment, which was built under contract to the International Telecommunications Satellite Organization (INTELSAT), has been qualified for flight and is waiting for a flight assignment.

The tests performed to qualify these experiments for flight are described, and the lessons learned which can be applied to future GAS experiments are discussed. Finally, survey results from 134 GAS experiments flown to date are presented. On the basis of these results it is recommended that future GAS experiments be qualified to shuttle thermal and dynamic environments through a rigorous series of mission operating tests. Furthermore, should automatic activation of the experiment be required during the boost phase of the mission, NASA-supplied redundant barometric switches should be employed to trigger the activation.

The two GAS experiments built by McDonnell Douglas are identified below. The first experiment, G074, was flown on shuttle mission 41-G in October 1984. It was designed to investigate the operation of two-surface tension propellant acquisition concepts in low-g, self-filling gallery legs, and a refillable trap. The second experiment, G-522, was built under contract to INTELSAT and was designed to measure the low-g performance of two-propellant gaging concepts, ultrasonic point sensors, and a nucleonic gaging system. These gaging concepts are high value candidates for future geostationary satellites. The G-522 experiment has been qualified for flight and is now waiting for a shuttle flight assignment.

MCDONNELL DOUGLAS GAS EXPERIMENTS

11-6303

EXPERIMENT	DESCRIPTION
G-074	PROPELLANT ACQUISITION • SELF-FILLING GALLERIES • REFILLABLE TRAP
G-522	PROPELLANT GAGING • ULTRASONIC POINT SENSORS • NUCLEONIC GAGING

Figure 1

Two views of the G074 propellant acquisition experiment are shown in Figure 2. All experiment components were attached to a 6061-T6 aluminum frame structure. The top of the structure was centilevered from a NASA-supplied mounting plate, and the bottom of the structure was supported laterally by four pads which pressed against the walls of the flight canister. The experiment components consisted of a test tank, positive displacement accumulator, valves and plumbing, control electronics, batteries, and a movie camera and lighting system.

The experiment was designed to be activated automatically at launch by redundant acoustic switches. This technique was used successfully on a previous NASA-Goddard GAS experiment. The switches were set to sense acoustic pressure levels at main engine ignition and then trigger the experiment's control and timing circuits.

The experiment weighed 106 pounds and was installed in a 5-cubic-foot GAS canister. A detailed description of the G074 experiment is contained in Reference 1.

G074 EXPERIMENT

11-6294

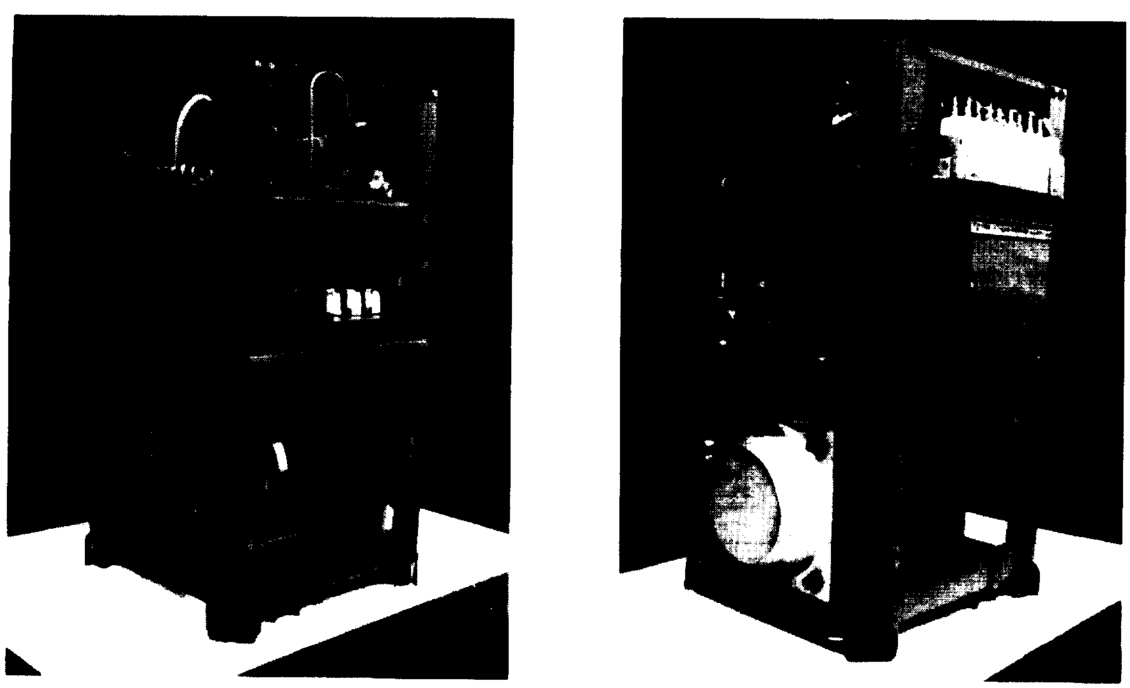


Figure 2

The test tank (Figure 3) is a bolted assembly consisting of a cylindrical Plexiglas section, an aluminum forward dome, and an aluminum aft end plate. The tank is divided into forward and aft compartments by an internal Plexiglas bulkhead. The three gallery legs in the forward compartment are made of Plexiglas to allow visual (movie) evaluation of gallery filling during zero-g. Each gallery leg has a flat, stainless steel screen surface along its outer face (adjacent to the tank wall) and a vent screen inside the forward vent baffle assembly. Gallery leg dimensions and screen mesh sizes are varied in order to acquire parametric data during the gallery fill process.

The internal bulkhead assembly contains a tapered Plexiglas vent stack to provide an exit passage for entrapped gas during passive fill of the aft trap compartment. The vent stack is covered by two perforated plate discs at its forward end.

TEST TANK FOR SHUTTLE EXPERIMENT

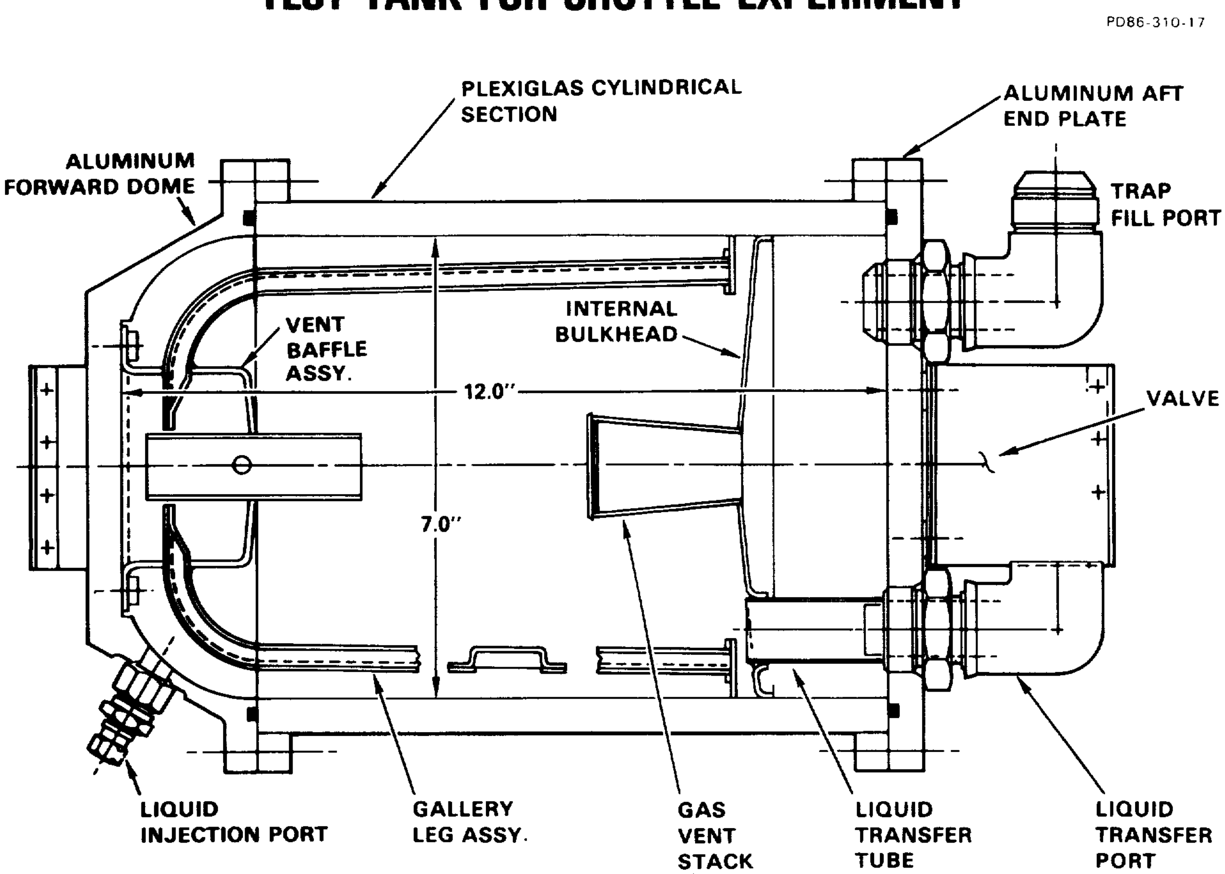


Figure 3

The tank operating sequence is shown in Figure 4. The tank is launched with a partial liquid load (Freon 113) in the forward compartment and a nearly empty aft compartment. During the zero-g interval following main engine cutoff, the three gallery legs fill by capillary pumping. The baffle assembly at the forward end of the tank keeps the gallery vent screens dry until the gallery fill process is complete. The maximum gallery fill time is approximately 10 seconds.

After the first Orbital Maneuvering Subsystem (OMS) burn, additional Freon 113 is injected into the tank forward compartment from an auxiliary positive displacement accumulator in preparation for the trap filling experiment. The trap filling experiment is performed during the second OMS engine firing. The transfer valve at the tank outlet is signalled open to allow liquid flow from the forward to aft compartment. During the burn, gas inside the aft compartment is expelled through the vent stack perforated plates by the hydrostatic pressure imposed across the entrapped gas bubble, allowing the aft compartment to fill. The aft compartment fill rate is retarded by liquid flow pressure losses through the transfer line and valve and by gas flow pressure losses through the vent stack perforated plates. For an OMS acceleration of 0.04 g's, the aft compartment fill time is approximately 30 seconds.

OPERATING SEQUENCE: G074 EXPERIMENT

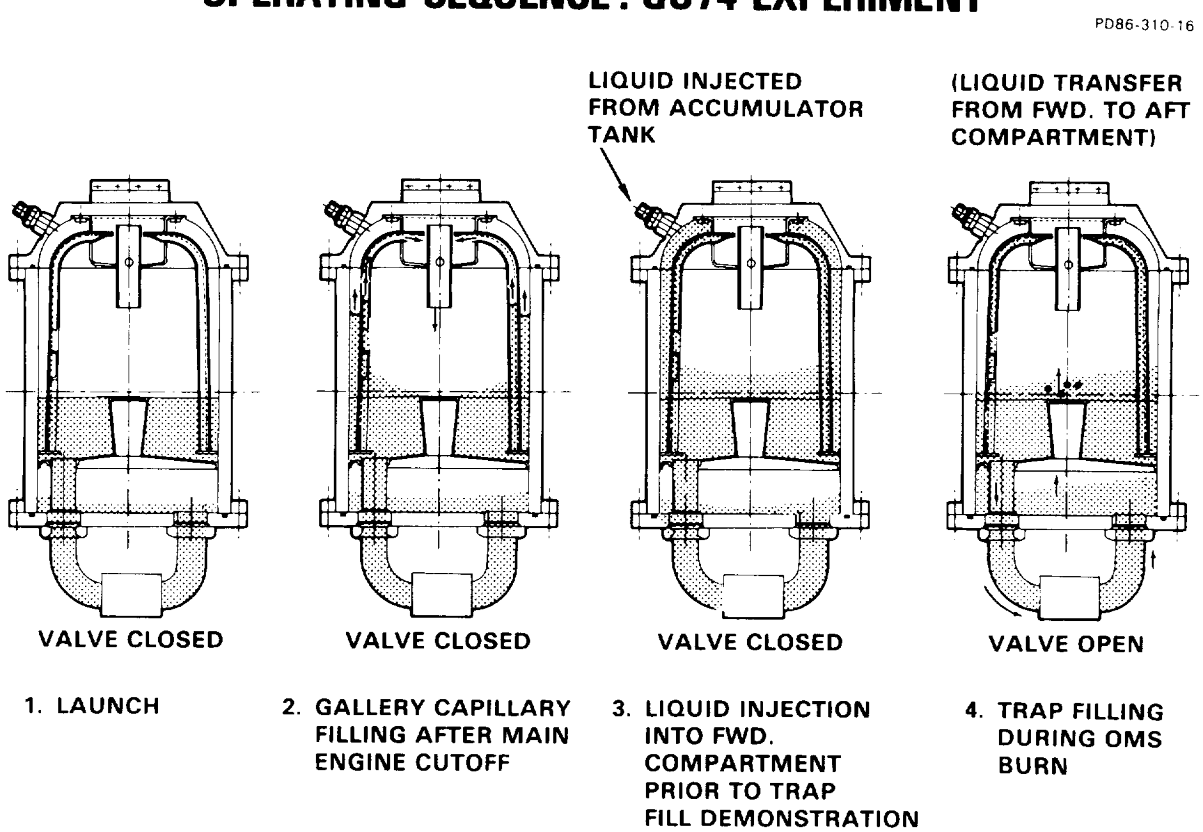


Figure 4

Environmental testing was performed to qualify the experiment for flight. The testing consisted of high and low temperature operating tests, vibration tests and acoustic tests.

The high and low temperature tests were performed by installing the fully serviced payload inside an insulated thermal enclosure. Conditioned air at 65°C or nitrogen at -28°C was circulated through the enclosure to bring the payload to equilibrium. The payload was activated, and an entire mission sequence was run while maintaining the equlibrium temperature.

The vibration tests were performed with the fully serviced payload installed in a NASA shipping cylinder to simulate the flight canister. The imposed vibration spectrum (6 g_{RMS} - overall) was in accordance with the NASA flight specification for GAS payloads. Tests were performed in each of three axes (2 lateral and 1 vertical) for 40 seconds per axis.

An acoustic test was performed to verify the operational integrity of the payload following vibration testing. An acoustic environment was imposed which duplicated the sound pressure level and frequency spectrum measured inside the GAS canister on the STS-3 mission at liftoff. The payload was activated successfully with its acoustic switches at a threshold sound pressure level of 110 dB, and an entire mission sequence was run.

FLIGHT CERTIFICATION TESTS: G074 EXPERIMENT

11-6304

- PROOF PRESSURE
- ROOM TEMPERATURE MISSION SEQUENCE
- HIGH TEMPERATURE MISSION SEQUENCE
- LOW TEMPERATURE MISSION SEQUENCE
- VIBRATION TEST
- ACOUSTIC TEST
- ROOM TEMPERATURE MISSION SEQUENCE

Figure 5

The G074 experiment was flown on shuttle mission 41-G in October 1984. A review of the test films revealed that the experiment was activated on the ground, prior to flight. It is believed that the experiment's acoustic switches were triggered by a Delta launch one day after the experiment was installed in its flight canister. The Delta launch pad is adjacent to the GAS payload processing facility, and acoustic levels during a launch are reported to be quite high.

To obtain the desired zero- and low-g data, the experiment was flown in a NASA KC-135 flight test on 5 March 1986. The experiment operated successfully during this flight test and, as such, a second shuttle flight is not planned.

FLIGHT RESULTS: G074 EXPERIMENT

11—6305

- FLOWN ON SHUTTLE MISSION 41G (5 OCT 84)
- EXPERIMENT ACOUSTIC SWITCHES ACTIVATED PREMATURELY BEFORE FLIGHT
- EXPERIMENT COULD NOT BE RESET AND WAS NOT ACTIVATED DURING FLIGHT
- EXPERIMENT OPERATION AT ZERO-& LOW-G VERIFIED ON KC-135 FLIGHT TEST (5 MAR 86)
- SHUTTLE REFLIGHT NOT PLANNED

Figure 6

Based on the GO74 flight experience, it is recommended that use of acoustic or "g" switches for experiment activation be avoided. If experiment activation during boost is required, then barometric switches (which sense atmospheric pressure) should be used. Because of the GO74 failure, NASA-Goddard is now providing redundant barometric switches as a standard service for GAS payloads.

LESSONS LEARNED: G074 EXPERIMENT

11-6306

- AVOID USE OF ACOUSTIC OR "G" SWITCHES TO ACTIVATE EXPERIMENT DURING BOOST
- IF EXPERIMENT ACTIVATION DURING BOOST IS REQUIRED, USE BAROMETRIC SWITCHES
- BECAUSE OF G074 FAILURE, NASA-GODDARD IS NOW PROVIDING REDUNDANT BAROMETRIC SWITCHES AS STANDARD SERVICE FOR GAS PAYLOADS

Figure 7

The purpose of the G522 experiment (Figure 8) is to provide an orbital test of ultrasonic point sensor and nucleonic gaging systems. The experiment consists of the following elements:

- o Plexiglas test tank with ultrasonic and nucleonic gaging systems
- o Two-liquid supply (positive displacement) accumulators with associated valving and plumbing
- o Support structure
- o Power supply
- o Control electronics and data acquisition system
- o Movie camera and lighting

The overall experiment weighs 145 pounds and will be contained within a standard 5-cubic-foot GAS canister. The canister will be purged and pressurized with dry nitrogen gas to 14.7 pounds/square inch-absolute prior to installation into the Orbiter.

A complete description of the experiment is contained in Reference 2.

G522 EXPERIMENT

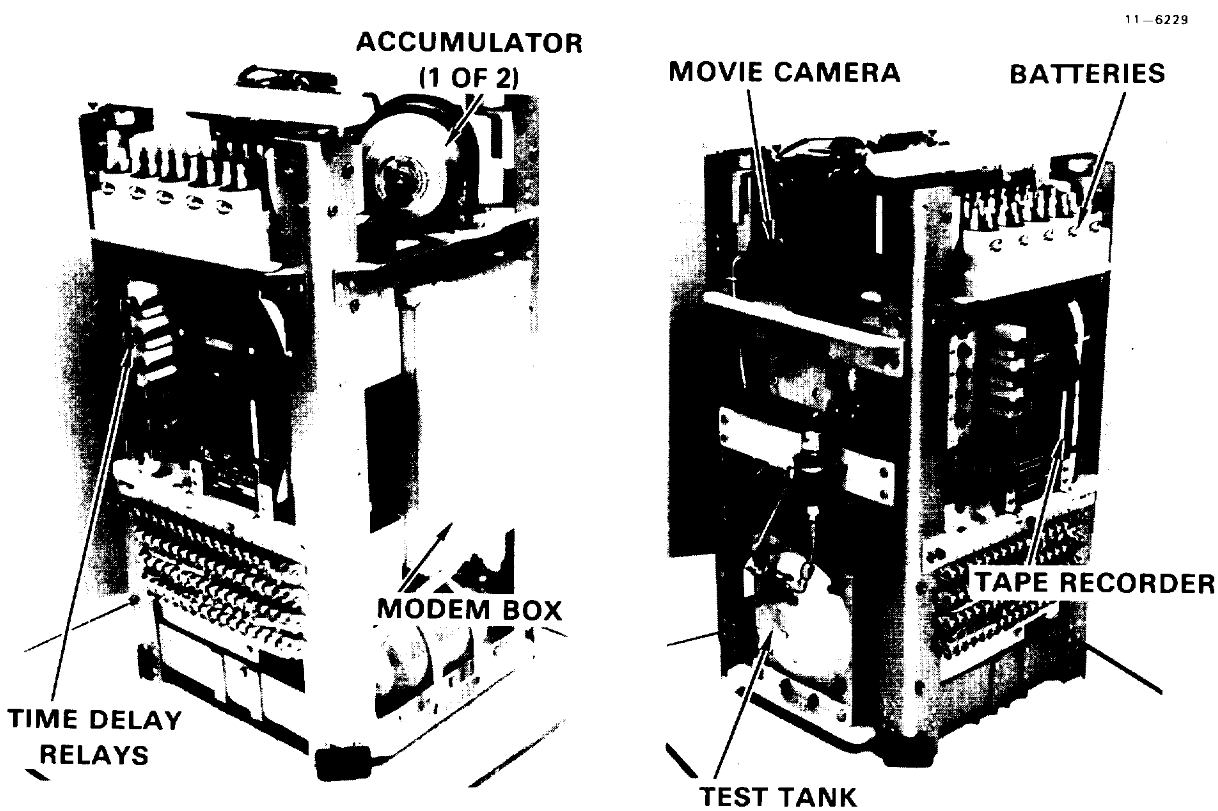


Figure 8

In order to permit packaging all required equipment within the 5-cubic-foot GAS canister, a small 5.75 by 8 inch tank was selected having an internal shape simulating a cylindrical propellant tank with ellipsoidal end domes.

As shown in Figure 9, the tank is a bolted assembly consisting of a cylindrical Plexiglas section, internal vane device for liquid positioning, and aluminum end domes. The Plexiglas section is sealed against the end domes with rubber O-rings. The internal vane device consists of four radial vanes that position the test liquid (Freon 113) in a wall-bound orientation in zero-g.

TEST TANK: G522 EXPERIMENT

11 6028

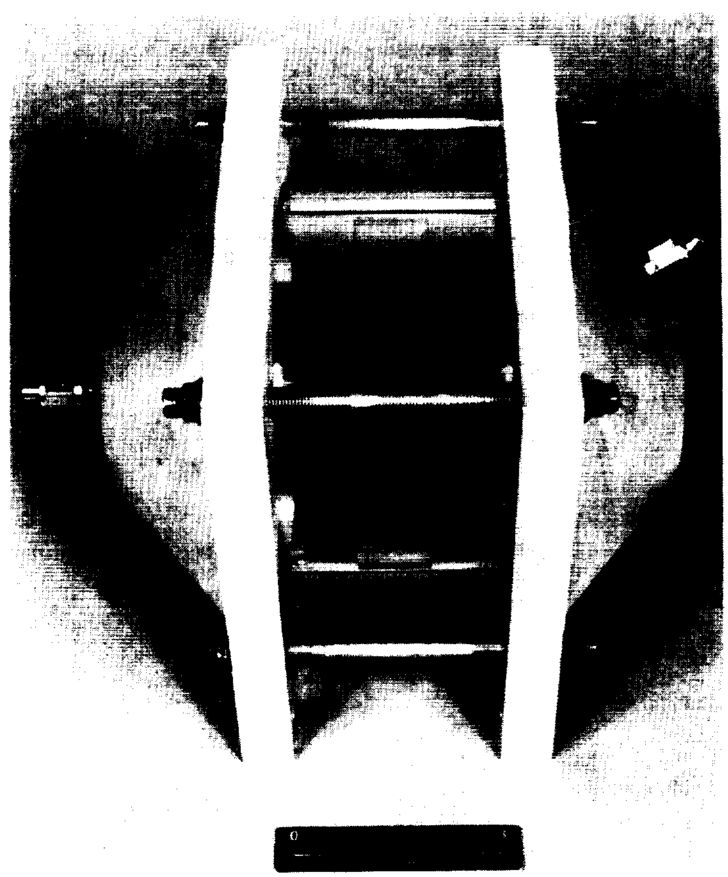


Figure 9

The experiment will be activated in orbit by astronaut command using the shuttle Autonomous Payload Control System (APCS). The APCS operates three GAS Control Decoder (GCD) relays in the base of the GAS canister.

GCD Relay A will be switched from latent to hot to activate the experiment and measure background radiation levels with a dry test tank using the nucleonic gaging system.

GCD Relay B will then be operated to (1) turn on the movie camera and lights, (2) inject 800 ml of Freon into the test tank, and (3) record gaging system and temperature data for three minutes.

Finally, GCD Relay C will be operated for another 3 minutes to record data after injecting an additional 450 ml of Freon into the test tank.

OPERATING SEQUENCE: G522 EXPERIMENT

11-6307

GCD RELAY A	TURNS DATA RECORDING SYSTEM ON FOR 3 MIN. TO MEASURE BACKGROUND RADIATION LEVELS
GCD RELAY B	• TURNS ON LIGHTS & CAMERA • ACTUATES VALVE TO INJECT 800 ML OF FREON INTO TEST TANK • RECORDS DATA FOR 3 MIN.
GCD RELAY C	• TURNS ON LIGHTS & CAMERA • ACTUATES VALVE TO INJECT 450 ML OF FREON INTO TEST TANK • RECORDS DATA FOR 3 MIN.

Figure 10

The experiment passed flight certification testing (thermal and vibration environments) during the week of 21 April 1986 and is now ready for flight. As shown by the figure below, the flight certification sequence was similar to that employed for the GO74 propellant acquisition experiment (Figure 5).

FLIGHT CERTIFICATION TESTS: G522 EXPERIMENT

11-6308

- PROOF PRESSURE
- ROOM TEMPERATURE MISSION SEQUENCE
- HIGH TEMPERATURE MISSION SEQUENCE
- LOW TEMPERATURE MISSION SEQUENCE
- VIBRATION TEST
- ROOM TEMPERATURE MISSION SEQUENCE

Figure 11

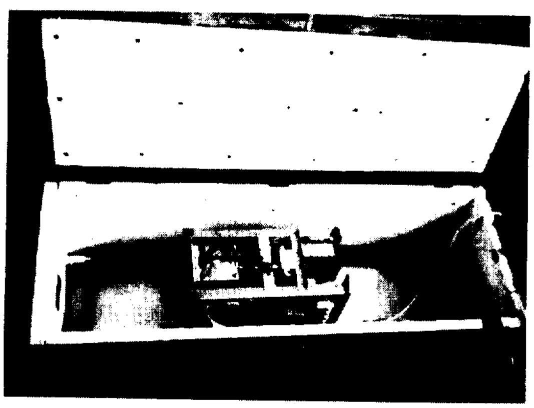
For thermal testing the experiment was placed in an insulated enclosure (Figure 12). First, liquid nitrogen was circulated through a finned heat exchanger in the base of the enclosure to achieve a stable experiment temperature of approximately -20°C. A fan inside the enclosure circulated the air to obtain a uniform temperature distribution. When the temperature stabilized, the experiment was operated for a complete mission sequence, and all functions were normal.

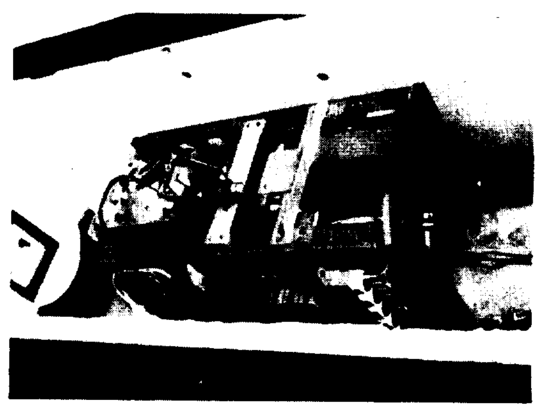
For the high temperature test, steam was circulated through the heat exchanger to obtain an experiment temperature of 45°C. Another mission sequence was run following temperature stabilization, and, again, all experiment functions were normal.

THERMAL TESTS OF G-522 EXPERIMENT

11-6235

EXPERIMENT INSTALLED IN THERMAL CONDITIONING ENCLOSURE





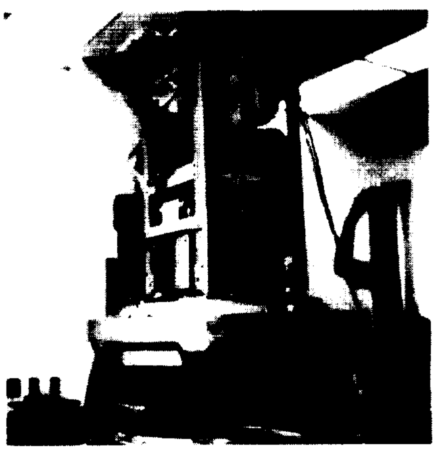
CONTROL & DATA MONITORING SYSTEM FOR THERMAL TESTS

Figure 12

The setup for random vibration testing is shown in Figure 13. The experiment was subjected to the NASA-specified spectra of 6 g's RMS for 40 seconds in each of its three principal axes. Following vibration testing, a mission operating sequence was run, in which all experiment functions were normal.

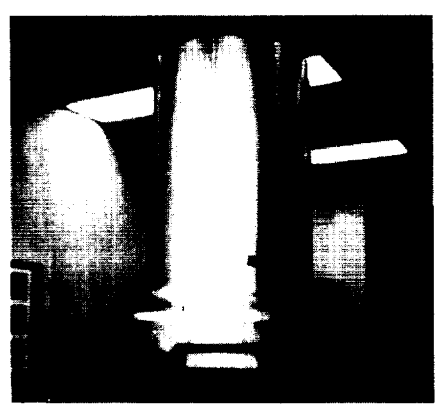
As a result of these successful environmental tests, the experiment has been placed in storage to await a shuttle flight assignment. After storage, additional room temperature operational checks will be performed to verify the experiment is ready for flight.

VIBRATION TESTS OF G-522 EXPERIMENT 11-6236



EXPERIMENT INSTALLED ON VIBRATION TABLE

INSTALLATION OF SHIPPING CYLINDER



SHUTTLE Z-AXIS VIBRATION TEST

Figure 13

A breakdown of failures experienced on GAS experiments to date is presented below. This survey was prepared by Dr. Ridenoure of Utah State University, and the results will be presented in detail at the 1986 Get-Away-Special Experimenter's Symposium to be held at NASA-Goddard this October. As shown, the failures can be categorized in five primary areas, with 6% of the failures having unknown causes.

Because of the high failure rate, all future GAS experiments should be subjected to shuttle thermal and vibration environments.

SURVEY OF GAS EXPERIMENTS FLOWN ON SHUTTLE (DR. RIDENOURE – UTAH STATE UNIVERSITY)

11-6309

- 54 SUCCESSES
- 80 FAILURES (EXPERIMENT OBJECTIVES NOT ACHIEVED)
- CAUSES OF FAILURES
  - 33% THERMAL (TEMPERATURES TOO LOW)
  - 25% CONTROLS (FAILURE TO ACTIVATE)
  - 14% MECHANICAL (FAILURE DUE TO VIBRATION)
  - 12% POWER (BATTERIES WENT DEAD)
  - 10% ATMOSPHERE (CANISTER LEAKED)
  - 6% UNKNOWN

Figure 14

Based on the results of Dr. Ridenoure's survey and experience gained in building two McDonnell Douglas experiments, a summary of recommendations for designing and testing future GAS payloads is presented in Figure 15.

SUMMARY
RECOMMENDATIONS FOR GAS PAYLOADS

11-6310

- PROVIDE SIMPLE, RUGGED DESIGN
- PROVIDE HIGH MARGIN FOR BATTERY POWER & LIFE (GATES LEAD-ACID & YARDNEY SILVER-ZINC & SILVER-CADMIUM CELLS ARE GOOD CHOICES)
- QUALIFY EXPERIMENT TO SHUTTLE ENVIRONMENTS
  - MINUS 20°C IF NO HEATERS ARE USED
  - NASA-GODDARD SPECIFIED VIBRATION ENVIRONMENT (6 G RMS)
  - CONDUCT COMPLETE OPERATIONAL TESTS
- AVOID ACTIVATION DURING BOOST. OTHERWISE, USE NASA-GODDARD REDUNDANT BAROMETRIC SWITCHES

Figure 15

References

1. Orton, G. F.: Design and Development of Shuttle Get-Away-Special Experiment G-074. NASA Conference Publication 2324, August 1984.

2. Orazietti, A.J.; Orton, G.F.; and Schreib, R.: Propellant Gaging for Geostationary Satellites. AIAA Paper 86-1716, June 1986.